PERFORMANCE OF NINE NORTHEASTERN POPLAR HYBRIDS IN COLORADO

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INTRODUCTION

Approximately the eastern one-half of Colorado consists of high plains, with relatively low annual precipitation, where natural tree vegetation is restricted to stream courses. The search for native or exotic species, or perhaps hybrid combinations, which may prove to be adapted to the harsh eastern Colorado upland farmstead and ranch conditions, is a constant one. Desirable features of trees for these conditions, in addition +.o inherent rapid growth rate, include resistance to frequent scanner and winter drought and tolerance to soils which are alkaline.

According to Little (1953), six species of Populus L. are native to the plains and mountain areas of Colorado. With the exception of the high altitude Populus tremuloides Michx. (quaking aspen) of the section Leuce, and Populus sargentii Dode (plains cottonwood) of the section Aegeiros, the remaining species are Tacamahaca poplars. These include P. X acuminate Rydb. (lanceleaf cottonwood), a natural hybrid between plains cottonwood and narrowleaf cottonwood; P. angustifolia James (narrowleaf cottonwood), a foothills species; P. balsamifera L. (balsam poplar), which reaches the southerly-most extent of its range in the mountains of north-central Colorado; and P. fremontii var. wislizenii S. Wats. Rio Grande cottonwood), which is restricted to the southern part of the state. No other genus is represented by as many tree species in Colorado as Popilus L. It therefore seems logical that clones of some of the hybrids developed by Stout and Schreiner (1933) in the Northeast, during the 1920's, may be useful in this state.

METHODS

In the spring of 1963, five stem cuttings, 1/4 to 3/8 inches in diameter and about six inches long, of each of nine Northeastern poplar hybrid clones in different combinations of six species plus one clone of Populus maximowiczii Henry were obtained from the Northeastern Forest Experiment Station see table I). These cuttings were rooted in clay pots in the greenhouse and transferred to the nursery while in leaf and held there for the remainder of the 1963 growing season, which all plants survived.

Table 1.--Clones and parentages of poplars tested near Fort Collins, Colorado, 1964 to 1967

Clone	Parentage
NE-17	P. nigra Linnaeus cv. Charkowiensis × P. nigra cv. Caudina
P. max.	P. maximowiczii Henry
NE-41	P. maximowiczii × P. trichocarpa Torrey & Gray
NE-212	P. deltoides Bartram × P. trichocarpa
NE-224	P. deltoides × P. nigra cv. Caudina
NE-236	P. deltoides × P. nigra cv. Volga
NE-254	P. deltoides cv. Angulata × P. trichocarpa
NE-274	P. sargentii Dode × P. simonii Carriere
NE-285	P. nigra × P. trichocarpa
NE-374	P. deltoides cv. Angulata × P. trichocarpa

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In April, 1964, the trees were planted at the Colorado State Forest Service nursery, two miles west of Fort Collins, Colorado (105° 05'W, 40° 35'N, 5000 feet altitude) in five east-west row plots, each row containing one randomly-located ramet of each of the ten clones. Spacing between and within rows was eight feet. Irrigation was restricted to an initial watering at the time of planting; the trees were cultivated as needed. The soil was a black, silty clay loam to clay loam with a pH of 8.4 to 8.6.

Initial height measurements were taken of all trees upon establishment of the plots. This height is equivalent to the 1963 growth. Thereafter, frequent periodic height measurements were mad(-. and the dates of bud burst and of height growth cessation were recorded during the 1964, 1965, and 1966 seasons, plus bud burst in 1967.

Analyses of variance were conducted for the surviving plants to determine whether significant between-tree and/or between-year variation existed in dates of bud burst and height growth cessation within any of the clones. The 95 percent confidence limits of four-year height growth, as well as those of dates of bud burst and height growth cessation were examined for differences between clones. In an effort to assess the relative merits of the clones, a scoring system was devised and values were arbitrarily assigned to features deemed suggestive of adaptation to Colorado conditions.

RESULTS

Phenology.--Figure 1 shows that the extreme dates of bud burst of the surviving plants, during four years of observation, varied from a six-day period in early May for Populus deltoides Bartr. cv. Angulata X P. trichocarpa Torr. & Gray (NE-254) to a 24-day period beginning about mid-April for P. nigra L. X P. trichocarpa (NE-285). P. nigra cv. Charkowiensis X P. nigra cv. Caudina 17) and P. sargentii Dade X P. simonii Carr. (NE-274) burst bud significantly earlier (95 percent level) than any of the five clones containing P. deltoides, or its cultivar Angulata, as the female parent. The other two surviving clones, P. maximawiczii X P. trichocarpa (NE-41), the Androscoggin poplar, and P. nigra X P. trichocarpa NE-285), the Roxbury poplar, exhibited great variation in bud burst date. Furthermore, these two clones contained some trees which did not survive; the non-survivors of these clones burst bud later than the survivors, apparently due to severe die-back during the preceding winter.

The extreme dates of height growth cessation of the surviving plants, observed at the end of three seasons extended over a longer period of time than did the dates of bud burst of the same clones, except for the Androscoggin poplar (NE-41) (fig. 1). Three clones containing P. nigra or one of its cultivars as either a male or female parent (NE-17, NE-224, NE-2 5 ceased height growth significantly later (95 percent level) than two of the clones containing P. trichocarpa as the male parent (NE-41 and NE-374). No other clones differed significantly from the earliest or the latest ones. Non-surviving plants ceased height growth sooner than surviving plants of the same clones; usually height growth cessation indicated death of these plants.

Table 2 shows that there was no significant difference found in bud burst date between trees within any of the clones. However, with the exceptions of the Androscoggin poplar (NE-41) and one of the P. deltoides cv. Angulata X P. trichocarpa clones (NE-374), date of bud burst differed significantly between years. This yearly variation in bud burst date is not surprising, because the latest date on which 28° F. 9r less was reached in Fort Collins varied from March 30 in 1965 to May 13 in 1966.[2]

[2] Data from the Colorado State University weather station. Twenty-eight degrees was taken as the level of a killing frost.

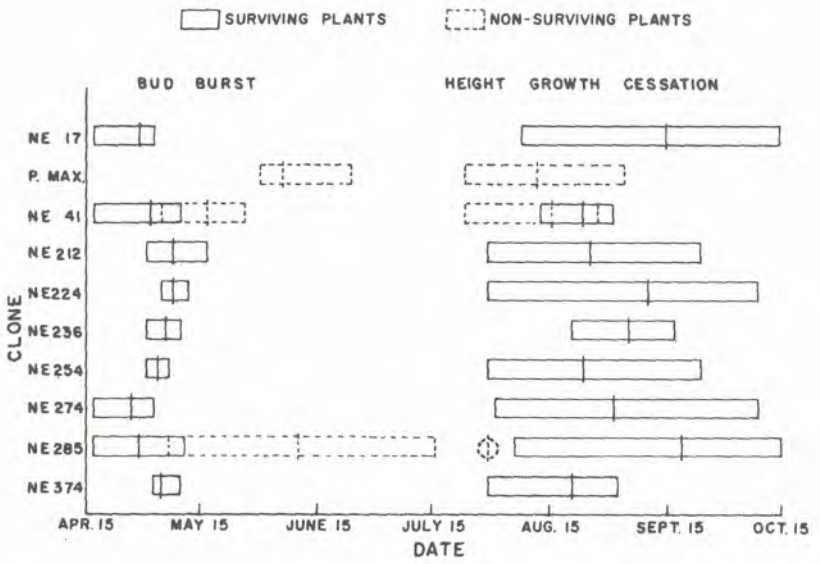

Figure 1.--Earliest, latest, and mean dates of bud burst and height growth cessation of hybrid poplar clones grown near Fort Collins, Colorado, 1964 to 1967. One tree of NE-236 did not burst bud in 1964.

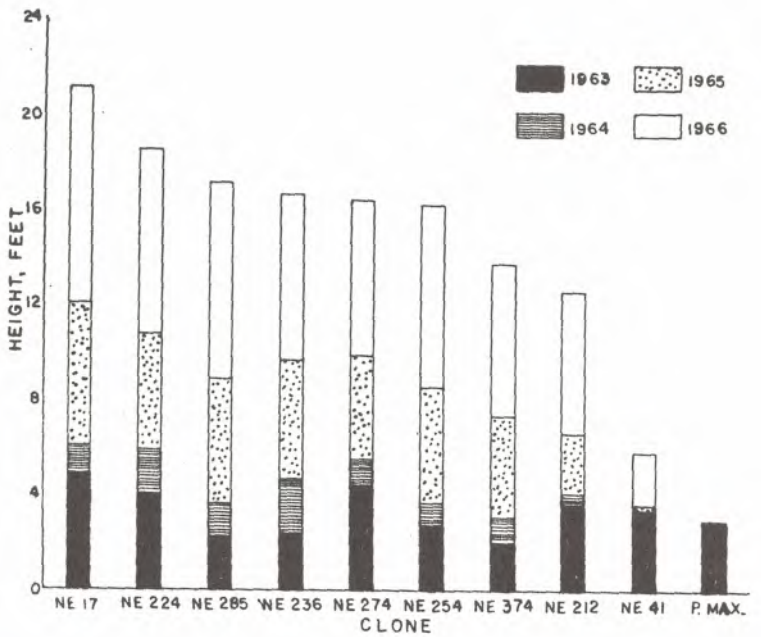

Figure 2.--Mean heights of surviving hybrid poplar clones planted near Fort Collins, Colorado.

With one exception, namely P. deltoides X P. nigra cv. Caudina (NE-224), there was no significant difference in the date of height growth cessation between trees within clones (table 2). However, four of the five clones tested, which contained P. deltoides as the female parent, differed significantly in the date of height growth cessation between years. All other clones were non-significant.

Table 2.--Variation in dates of bud burst and height growth cessation within surviving poplar clones grown near Fort Collins, Colorado, 1964 to 1967

Clone	Survival 1967	Date of bud burst			Date of height growth cessation		
		Mean	Variation between		Mean	Variation between	
	Percent		Trees	Years		Trees	Years
NE-17	100	Apr. 29	NS	**	Sept. 15	NS	NS
P. max.	0	1/	1/	1/	2/	2/	2/
NE-41	40	May 2	NS	NS	Aug. 24	NS	NS
NE-212	100	May 8	NS	*	Aug. 26	NS	**
NE-224	100	May 8	NS	**	Sept. 10	**	*
NE-236	80	May 6	NS	**	Sept. 3	NS	NS
NE-254	100	May 4	NS	*	Aug. 23	NS	**
NE-274	100	Apr. 27	NS	**	Sept. 1	NS	NS
NE-285	60	Apr. 29	NS	**	Sept. 19	NS	NS
NE-374	100	May 5	NS	NS	Aug. 21	NS	**

1/ No trees of Populus maximowiczii Henry survived the 1964 growing season.
2/ Date of height growth cessation was not observed in 1963.
NS No significant difference in dates between trees or between years within the clone.
* Significant difference within clone at 95 percent level of probability.
** Significant difference within clone at 99 percent level of probability.

Survival.--The poorest survival of any clones was obtained from Populus maximowiczii Henry and from the hybrid containing this species as one parent, the Androscoggin poplar (NE-41). None of the members of the species clone survived the first season in the out-planting plots (1964). Although three individuals of the clone sprouted weakly from the base during June, two individuals did not burst bud at all; all were severely injured during the preceding winter.

All of the individuals of the hybrid clone P. maximawiczii X P. trichocarpa (NE-41) also suffered severe die-back during the winter prior to establishment of the plots. Three of these sprouted weakly from the base in late spring, 1964 and died during that summer. The two surviving plants have been repeatedly killed back, reducing them to shrubby individuals. Although the Roxbury poplar, P. nigra X P. trichocarpa (NE-285) and P. deltoides X P. nigra (NE-236) clones incurred some mortality, the surviving plants have done well; all other clones tested have survived the four years to the present 100 percent.

Thus, both clones containing P. maximowiczii have suffered severe mortality; two of the four clones containing P. nigra (including cultivar Volga) shaved some mortality, the poorer when in combination with P. trichocarpa. Only one of five clones containing P. deltoides showed any mortality (with cv. Volga), and both clones containing P. nigra cv. Caudina survived 100 percent.

Height growth. --Figure 2 shows that the four-year height growth of surviving plants was the greatest for the combination of P. nigra cultivars Charkowiensis X Caudina (NE-17), which averaged 21.1 feet. Four-year height growth was least for the two survivors of the Androscoggin poplar (NE-41), which averaged 5.8 feet. This figure also shows that, except for the weak Androscoggin poplar, the 1966 growth was the greatest of any year for all other clones. This may have been due to greater-than-normal precipitation during 1965. However, it also suggests that competition between the trees spaced 8 X 8 feet, had not yet become keen enough to affect height growth much in 1966.

Interestingly enough, the mean height of only NE-212 (P. deltoides X P. trichoca a at 12.6 feet was significantly (95 percent level) less than the tallest clone (table 3). That the Androscoggin poplar was not statistically shorter than any of the other clones was due to the low number of survivors and the relatively large variation in height between them.

Table 3.--Four-year height of poplar hybrid clone survivors grown near Fort Collins, Colorado, October, 1966

Clone	Mean height	Fiducial limits[1]
	Feet	Feet
NE-17	21.1	4.86[3]
NE-41[2]	5.8	17.80
NE-212	12.6	1.89[3]
NE-224	18.5	6.86
NE-236[2]	16.6	4.75
NE-254	16.2	2.84
NE-274	16.4	2.67
NE-285[2]	17.1	3.84
NE-374	13.7	4.86

1/ Standard error x $t_{.025}$ (95 percent confidence limits).
2/ Survival was less than 100 percent.
3/ The mean height of NE-17 differed significantly from that of NE-212. No significant differences in average height among any other clones were detected.

Total four-year performance.--Using relative values for survival, die-back, date of bud burst, date of height growth cessation, and annual height growth, a total score for performance of 60 was possible. Five clones scored above 40 (table 4). Two of the three highest-scoring clones were the combinations P. deltoides cv. Angulata x P. trichocarpa (NE-254 and NE-374). Two other clones of the top five contained P. nigra cv. Caudina as the male parent (NE-17 and NE-224), and the fifth high-ranking clone was P. sargentii X P. simonii (NE-274), the female species native to Colorado, the area of testing, and the male parent from China (Bailey, 1949). The two poorest performers were the Japanese Populus maximowiczii and its hybrid, the Androscoggin poplar.

Table 4.--Four-year performance of poplar clones grown near Fort Collins, Colorado

Clone	Survival 1967	Die-back		Earliest bud burst date	Latest height cessation date	Average survivor height growth				Total
		Slight	Total			1963	1964	1965	1966	
		Relative Score[1]								
NE-17	15	4	10	0	0	3	1	4	5	42
P. max.	0	5	0	5	4	2	0	0	0	16
NE-41	6	5	0	0	4	2	0	1	1	19
NE-212	15	2	8	3	2	2	0	1	4	37
NE-224	15	5	10	3	0	3	1	3	5	45
NE-236	12	2	8	3	2	1	1	3	4	36
NE-254	15	5	10	3	2	2	0	3	5	45
NE-274	15	5	10	0	0	3	1	3	4	42
NE-285	9	1	8	0	0	1	1	3	5	28
NE-374	15	5	10	3	4	1	1	3	4	46

1/ Maximum possible in each category: Survival, 15; die-back, 15; bud burst date, 5 (0 = earliest five-day period, April 16 to 20); height growth cessation date, 5 (0 = latest ten-day period, Oct. 6 to 15); average height growth, 5 per year (0 = less than 1.0; 1 = 1.0 to 2.5; etc., in 1.5-foot intervals).

DISCUSSION

Although extensive testing of the clones used in this study has been conducted, most has been restricted to =astern Jniteu States. Some of the Oxford Paper Company clones selected from hybrids of Stout and Schreiner **(1933)** have been tested in the Lake States, the Pacific Northwest, and the N--braska sandhills (Forest Genetics Research Foundation, 1962), but no direct comparisons to Colorado conditions ar available.

Phenology.--The results of this study tend to support the generally accepted tenet that bud burst is strongly influenced by temperature (Pauley, 1958; Limstrom, 1965). During the four years of observation, most clones broke bud early in the years when the last killing frost in Fort Collins was early (1965, March 30; 1967, April 23) and late when the last killing frost was late (1964, April 26; 1966, May 13). The two years with the earlier last killing frost, followed years of less than eight inches total precipitation. The latest late spring frost, in the years observed, followed a year of over 16 inches precipitation, somewhat above normal for Fort Collins. Whether or not precipitation of the previous year combined with spring temperature to affect bud burst is not known.

The lack of significant differences in bud burst between years for the NE-41 and NE-374 clones suggests that leafing out of these clones may be inherently triggered by the spring temperatures of the cooler years. Variation in bud burst date is common in Populus. Ford and Sucoff (1961), for example, found that all clones containing one parent of P. maximowiczii, planted near Beltsville, Maryland, leafed out earlier than most of the 120 clones tested. The Androscoggin poplar (NE-41), in the Colorado study contains P. maximowiczii germ plasm. And Farmer (1966) found in the lower Mississippi valley that clones of early leaf flushers of P. deltoides, one of the parents of the NE-374 clone, can be established by simply taking cuttings of early-flushing individuals which are found in natural stands.

Most studies in the genus Populus L., in which height growth cessation and winter dormancy have been investigated, have shown that these phenomena are influenced by an interaction between the genotype and the photoperiod of the native environment. Pauley and Perry (1954) working with Populus trichocarpa, further found that hybrids between clones from northern and southern origins were intermediate between the parents in height growth cessation, suggesting genetic control of many genes. However, the authors were unable to account for all variation in height growth cessation within clones. Nitsch (1957) stated that the growth of Populus tacamahaca Mill. (= P. balsamifera L.), also of the section Tacamahaca (Rehder, 1940) was completely stopped by short days, the terminal growing point remaining alive but becoming enclosed in scales.

This study showed that the date of height growth cessation in four of the five clones tested containing P. deltoides (or its cultivar Angulata) differed significantly in different years but between trees within only one of these clones. Most of the yearly variation, however, seemed to be due to early cessation of height growth in 1964 and could have resulted from the shock of transplanting while establishing the plots. Yet, the possibility exists that unknown factors of the environment, other than or in addition to photoperiod, may be important in inducing winter dormancy in some Aegeiros poplars.

Survival and growth.--Failure of survival or poor growth of plants in a given locality may result from one or more abiotic, biotic, or genetic causes. Not only must the genotype be adapted to the physical environment in question, but it must also resist insects and disease, if it is expected to prosper.

Several eastern studies on strip mine spoil banks have shown that many poplar clones survive in higher proportions and grow at faster rates on sites with pH values above 4.0 than below it. Davis (1964) found in Pennsylvania that as pH varied on different areas from 3.1 to 5.7, two-year survival of trees from 60 clones increased from 18 percent to 98 percent, and height increased from 0.7 feet to 7.2 feet. Roehrs and Davis (1965) also found survival and growth to be closely related to soil acidity on Pennsylvania spoil banks. Trimble (1963) found that the addition of 22 tons of ground limestone per acre to high altitude plots in West Virginia improved three-year survival from 20 percent to 80 percent and also increased the growth of the survivors of 50 selected poplar clones. Clonal differences were somewhat obscure in these studies on acidic soils, but they were pronounced on the limed plots in West Virginia.

Apparently, high pH values can be reached at which the survival and growth trends are also adversely affected. Funk (1963), studying 50 hybrid poplar clones in Ohio, found that survival and height growth were both better on a soil with 5.5 pH than on a soil with 7.0 to 7.5 pH. He found that after 10 years, P. deltoides x P. nigra cv. Caudina (NE-224) showed 50 percent survival and 21.0 feet height (2.1 feet per year) on the higher pH, 69 percent survival and 26.2 feet height on the lower pH soil. In the present study, however, this clone (NE-224) has survived 100 percent for four years, and the average annual height growth has been 4.6 feet on soil varying in pH from 8.4 to 8.6. Thus, the effect of soil pH on growth and survival of hybrid poplar clones is not clear.

Occasional or frequent die-back, often resulting from lack of winter hardiness, may also influence survival and growth of certain poplar clones. Stout and Schreiner (1933) reported that seedlings of P. maximowiczii suffered from frost and winter injury in Maine but that hybrids containing this parent seemed hardy. In other studies, the Androscoggin poplar, P. maximowiczii x P. trichocarpa (NE-41), performed well. Davis (1964) found that seven of nine clones listed among the "ten best" occurring on three or more of six Pennsylvania strip mine locations were of this clone, two years after establishment. Eschner (1960) also found that after nine years on two West Virginia alluvial sites, this clone had averaged 4.5 feet per year.

On the other hand, after four years in plantations in North Dakota and in Minnesota, the Lake States Forest Experiment Station (1939) found that two of four clones containing this Asiatic species were dead, and the other two survived 11 and 5 percent and averaged 7.4 and 7.7 feet in height respectively. Later Lake States tests reported by Rudolph (1948) corroborated these results. The Androscoggin poplar (P. maximowiczii X P. tricho carpa), though still surviving 58 percent after seven years, was expected to die out completely, due to canker attacks. This clone performed poorly in Colorado, also.

One of the best-performing clones in the Lake States Studies, Henry 2, was P. deltoides cv. Angulata X P. trichocarpa. This clone survived seven years 100 percent and averaged 30 feet in height. Similar results were obtained in Colorado.

But P. deltoides X P. nigra cv. Caudina (NE-224), as well as a clone of P. nigra cv. Charkowiensis X P. nigra cv. Caudina, which performed well in Colorado, were reported by Eschner (1960) to be complete failures in West Virginia.

It may be too early to assess the total performance of the nine poplar hybrids studied in Colorado. Schreiner and Stout (1934) pointed out that hybrids containing P. trichocarpa were very vigorous during the early years but later suffered severe injury from Melempsora rust. Perhaps the possibility of susceptibility to Colorado insects and diseases has not yet been tested. However, in view of the observations made on the hybrids studied to date, Populus deltoides, Populus sargentii, and Populus nigra, especially the cultivars Charkawiensis and Caudina, appear to be the most suitable parents for Colorado. In hybrid combination, Populus trichocarpa seems dominated by the other parent for the performance characteristics investigated.

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